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Original communication

The effect of weather conditions on burnt bone fragmentation

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A B S T R A C T

This research assesses how weather conditions, such as temperature and rainfall, affect the fragmentation of burnt bone. The recovery of human remains from fatal fire scenes is often hampered by the fragmentary nature of the material, and through understanding how weather factors affect this fragmentation, it may be possible to adjust recovery timelines and protocols to maximise the quantity and quality of condition of the material recovered. These data are also valuable as a baseline for expected fragmentation, and expected differences in fragmentation, under different weather conditions.

Sus scrofa (domestic pig) limbs were burned in a series of wood fires spaced over a period of eight months, from winter through fall, in a warm summer continental climate (Köppen-Geiger classification Dfb). Bone fragments were sorted by size and the proportional weights of each size category were compared to isolate any differences in fragmentation. Results suggest that in freezing conditions with remains recovery occurring the day after the fire, increased fragmentation is observed in younger remains but not in older remains. In older remains fragmentation is highest when temperatures fluctuate around 0 °C. It was observed that when remains recovery is delayed, fluctuating temperatures have a larger impact on fragmentation in the short term and freezing conditions are more significant in the longer term. Wet weather conditions increase levels of fragmentation.

1. Introduction

Fatal fires, or fires involving human remains, are not an uncommon scene encountered by police, medical examiners, and coroners in North America. Data from the 2002 Fire Loss report shows an average of 368 annual fire deaths between 1993 and 2002 in Canada,[1] and in the province of Alberta, 274 fire related deaths were investigated by the Office of the Chief Medical Examiner in the ten year period between January 1999 and December 2008.[2] Such scenes, especially when all soft tissue is destroyed and the remaining bone is burnt, are particularly challenging to the investigators responsible for the detection, recovery, examination, and analysis of human remains. Anthropological analysis of these human remains can be highly informative, and to capitalize on this information gain scene recovery efforts need to be optimised to guarantee a high quantity and quality of recovered material. One aspect of ensuring a good recovery is a thorough understanding of how remains fragment. Burnt bone is prone to progressive fragmentation[3,4] and knowledge of this process and the factors that affect it will allow investigators to minimise post-burning fragmentation through developing scenario-specific recovery protocols and timelines. Valid expectations of remains condition will allow investigators to determine the training required by searchers and will give searchers some indication of the condition of the remains, enhancing their ability to discover bone material. This will ensure that optimal search strategies, like employing a walking search pattern to identify larger bone elements or a hands and knees search to locate smaller calcined bone fragments, are used from the beginning of the search process. Decisions on equipment, for example, the use of heavy machinery or the size of screening mesh, can also be made appropriately as can judgements on procedural decisions such as removing fire debris or leaving material *in situ*. Knowledge of fragmentation systems will also facilitate a more streamlined recovery process as it can be appropriately organised and prioritized with other components of the investigation to insure minimal information loss for all involved.

Knowledge of how weather conditions affect fragmentation is an important element for understanding how bone responds to the burn environment and the fragmentation that will be encountered during recovery.[5] In regions which experience significant shifts in weather conditions, burnt bone may be exposed to very different conditions with different effects on fragmentation. To assess accurately the expected fragmentation and develop appropriate recovery systems, these factors need to be taken into consideration.

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Some key conditions which likely affect fragmentation levels are rainfall, snowfall and freeze–thaw cycles.

When human remains are burnt the soft tissue is destroyed, exposing the bone to the burn environment. As bone burning progresses, the bone material is transformed from its natural state to calcined bone through a number of intermediary stages which result in observable heat-induced changes in gross and microscopic appearance, color, size and shape.[5–7] During burning, as bone loses water and organic components and the hydroxyapatite crystals increase in size, overall size and shape changes affect the structural integrity of the bone material by altering the stress–strain relationships within each bone element leading to mechanical failures and fracturing. The loss of organic material reduces bone elasticity, further promoting fragmentation of fully calcined material.[8–11]

Heat-induced changes observed in burnt bone have a negative impact on recovery and anthropological analysis.[3,5] Small bone fragments are difficult to locate and recover and can prove challenging to identify; however, physical anthropologists are adept at reconstructing remains from fragments, and recent research describing heat-induced bone changes is enabling investigators to interpret burnt remains more effectively.[4,6,9,12–16] Significant improvements in the recovery of material from the scene[17] can still be made by increasing the quantity and quality of material recovered, facilitating more thorough skeleton reconstruction and strengthening analysis and the interpretation of evidence.

2. Methods and materials

To investigate the effect of weather conditions on bone fragmentation, fleshed *Sus scrofa* (domestic pig) limbs were burnt in a series of outdoor wood fires at different times of year as outlined in Tables 1 and 2. Burns were conducted in March, June and November in a warm summer continental climate, Köppen-Geiger classification Dfb (defined as fully humid, with the mean temperature of the coldest month ≤ -3 °C, the mean temperature of the warmest month $\leq$22 °C, and the mean temperature for at least four months $\geq$10 °C).[18] The March burn had ambient temperatures consistently below 0 °C and is referred to as the *Freezing burn*. Significant rainfall was experienced during the June burn and it is referred to as the *Wet burn*. The November burn is referred to as the *Fluctuating burn* as ambient temperatures fluctuated around freezing on a daily basis during the recovery period. Limbs from piglets and older post-weaning pigs (fattening pig stage) were burned and different delay-until-recovery periods were investigated to replicate typical fatal fire scenarios. Piglet limbs were aged at six weeks and were obtained from the Swine Research Facility at the University of Alberta where they had been euthanized for other research projects. Fattening pig limbs were sourced from a local butcher, and as such their exact age at death was unknown, but their close size and patterns of unfused epiphyses suggest they were all of a similar age, between 8 and 10 months based on standard slaughtering ages.[19] Fattening pig limbs were approximately twice the length of piglet limbs. The format for the burn events was such that all fires were started at approximately the same time on the burn day and were left to burn out and cool overnight before the timeline of recovery periods began the day after burning. Remains were recovered the day after burning (0 h delay) and at subsequent delay periods of 24 h, 56 h and 168 h (1 week) after the initial recovery to represent a range of time frames commonly encountered during fatal fire scene investigations as determined from viewing local Medical Examiner case files for Alberta. Wood burning fires were used to ensure a reasonably consistent burn environment across the burn events.

For each burn event *Sus scrofa* limbs were placed in two fires, one with piglet and fattening pig material for immediate recovery (0 h delay), and a second with fattening pig material for recovery following the three delay periods (24 h delay, 56 h delay, 168 h delay). In each fire, different aged limbs and limbs for each of the delay periods were placed in different segments of the fires, separated by 1.25 cm diameter, 0.5 m long iron rods (rebar). In the first burn event limbs were placed directly on the ground, and in latter burn events limbs were placed on a wood base to promote burning and calcination of inferior surfaces. Wood and newspaper were used to build stable, burnable structures that were lit and left undisturbed except for periodical additions of wood fuel. Wood fuel was added by hand, avoiding direct contact with the bone. Fires were sustained until full calcination was observed, at which point fires were left to burn out and cool overnight. Wood used consisted of a spruce/pine mix of 2″ × 4″ and 2″ × 6″ lumber, commonly found in the Alberta region and extensively used in home construction.[20] Similar burn time and temperature profiles for each limb group (piglet 0 h delay, fattening pigs 0 h, 24 h, 56 h and 168 h delay) were confirmed by temperature data collected using type J thermocouples placed amongst each limb group of both fires, with temperatures recorded at 1-min intervals using a DaqPRO 5300 datalogger (see Table 1).

Following burning, bone remains were recovered from the burn site at the specified delay periods. No evidence of animal disturbance to the remains was observed in any of the experiments. All remains were collected by the author by hand, using tweezers for smaller fragments with care taken to ensure no additional damage was done to any bone fragments. Bone fragments were stored in sealable plastic bags and supported by toilet tissue for immediate transport to the laboratory where they were removed from the bags, evaluated for any possible transportation damage, and stored on soft-surfaced paper trays. Care was taken to recover as much bone material as possible from the burn site, but some fragments were too small to be collected consistently and were thus necessarily excluded from data analysis. In the laboratory, bone was sorted by the author into one of 12 defined categories within three series based on size and shape (see Fig. 1). In the *Small series*

Table 1
The number of *Sus scrofa* limbs used in the burn events and burn characteristics for each limb group.

	Wet burn			Freezing burn			Fluctuating burn		
	# of limbs	T_{max} (°C)	Time at T_{max} (min)	# of limbs	T_{max} (°C)	Time at T_{max} (min)	# of limbs	T_{max} (°C)	Time at T_{max} (min)
Piglet 0 h delay	4	755	100	4	575	70	4	828	80
Fattening pig 0 h delay	2	741	100	3	701	70	1	848	80
Fattening pig 24 h delay	2	790	100	2	562	70	1	869	90
Fattening pig 56 h delay	1	843	60	2	–	–	1	843	70
Fattening pig 168 h delay	2	876	80	2	602	100	1	820	110

All limbs used were forelimbs except for fattening pig material in the Fluctuating burn which used hindlimbs.
T_{max} refers to the highest temperature reached in any one 10 min interval, averaged from 1 min data.
Time at T_{max} refers to the time since fire start and marks the beginning of the 10 min interval.
No temperature data was recorded for Freezing burn, fattening pig 56 h delay due to thermocouple probe failure.

Table 2
The weather conditions for the burn events.

	Month	Ave. °C on burn day	Ave. °C over 168 h	Snow/rain	Comments
Wet burn	June	12.3	11.8	Rain	Significant rain on first day of recovery. Occasional rain during following week
Freezing burn	March	−8.3	−3.5	Minor snow	Significant snow pack on ground. Falling snow did not accumulate on remains
Fluctuating burn	November	2	−1.1		Temperature fluctuated around 0 °C on a daily basis.

(categories 1–3) the shortest fragment dimension is less than 5 mm. Within this series in Category 1 the second shortest dimension (D2) is also less than 5 mm and the longest dimension (D3) is greater than 10 mm. In Category 2, D2 is greater than 5 mm and D3 is between 5 and 20 mm. In Category 3, D2 is again greater than 5 mm and D3 is greater than 20 mm. Categories 4–7 form the *Longitudinal series* where the shortest dimension (D1) is greater than 5 mm and the longest dimension (D3) is greater than twice the second longest dimension (D2). In Category 4, D1 must be less than 10 mm and D2 ranges between 5 and 10 mm with D3 being greater than 10 mm. In Category 5, D1 is again less than 10 mm but D2 is greater than 10 mm and D3 is greater than 20 mm. In Category 6, D1 ranges between 10 and 20 mm with D2 being longer than 10 mm and D3 longer than 20 mm. In Category 7, D1 and D2 are longer than 20 mm and D3 is longer than 40 mm. The third series, the *Non-longitudinal series*, consists of categories 8–12 and in this series the shortest dimension (D1) is greater than 5mm and the longest dimension (D3) is less than twice the second longest dimension (D2). In Category 8, D1 and D2 range between 5 and 10 mm with D3 ranging from 5 to 20 mm. In Category 9 D1 again ranges between 5 and 10 mm but D2 and D3 are greater than 10 mm. In Category 10, D1 and D2 are longer than 10 mm but shorter than 20 mm and D3 is longer than 20 mm. In Category 11, D1 ranges between 10 and 20 mm, D2 is shorter than 20 mm and D3 is greater than 20 mm. In Category 12 all three dimensions are greater than 20 mm. These categories were developed from the evaluation of preliminary test/practice burn events where material was sorted into perceived naturally occurring clusters.

Sieves were not used to separate material for two primary reasons. First, they can cause considerable mechanical damage to fragile materials and induce further fragmentation; and second, they do not allow for shape differences as fragments are sorted by only two dimensions. By measuring three dimensions fragments could be separated into three distinct shape series (Small, Longitudinal and Non-longitudinal) and fragmentation characteristics could be assessed within each series. The number of categories used was based on preliminary test/practice burns to ensure that size categorisations reflected the material at hand and did not arbitrarily divide clear size groupings and thus obscure any trends in the data. The size categories selected reflect clear clusters observed in the preliminary test/practice burns.

Following sorting, each category was weighed and the proportional mass calculated within each burn event (Wet burn, Freezing burn and Fluctuating burn). The proportion of the total mass accounted for by each category was calculated as a percentage within each limb group and burn event, allowing direct comparisons between each category in the different burn events.

3. Results

3.1. Small series

Fig. 2a shows the proportion of total mass accounted for by each category (proportional mass) in the Small series for each limb group. For the piglet remains proportional masses are highest in the Freezing burn and lowest in the Fluctuating burn for almost all

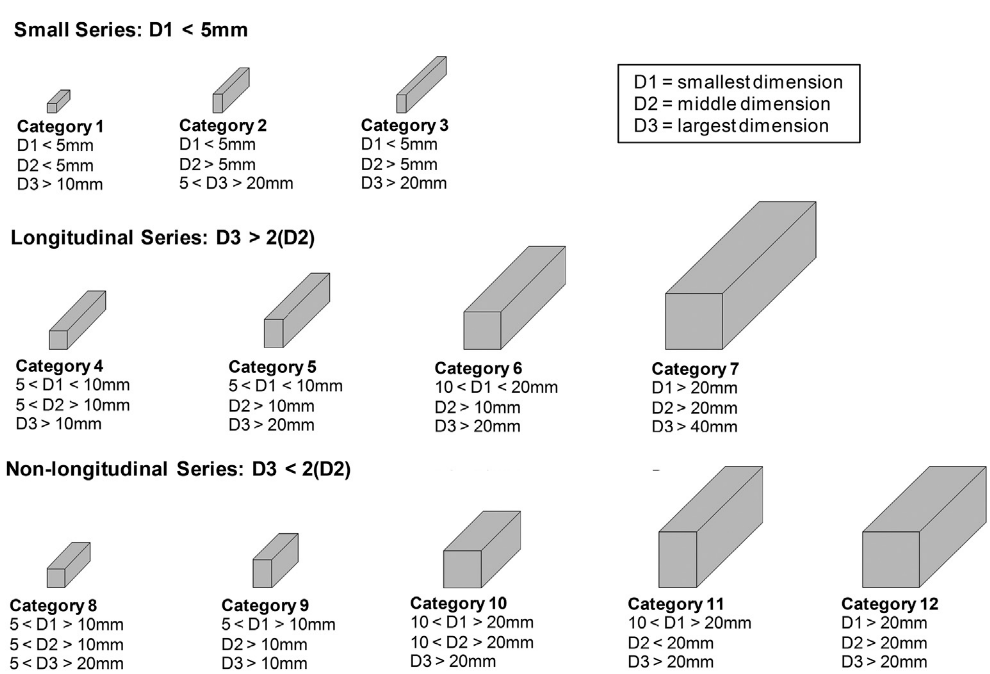

Fig. 1. Size categories used for sorting calcined bone.

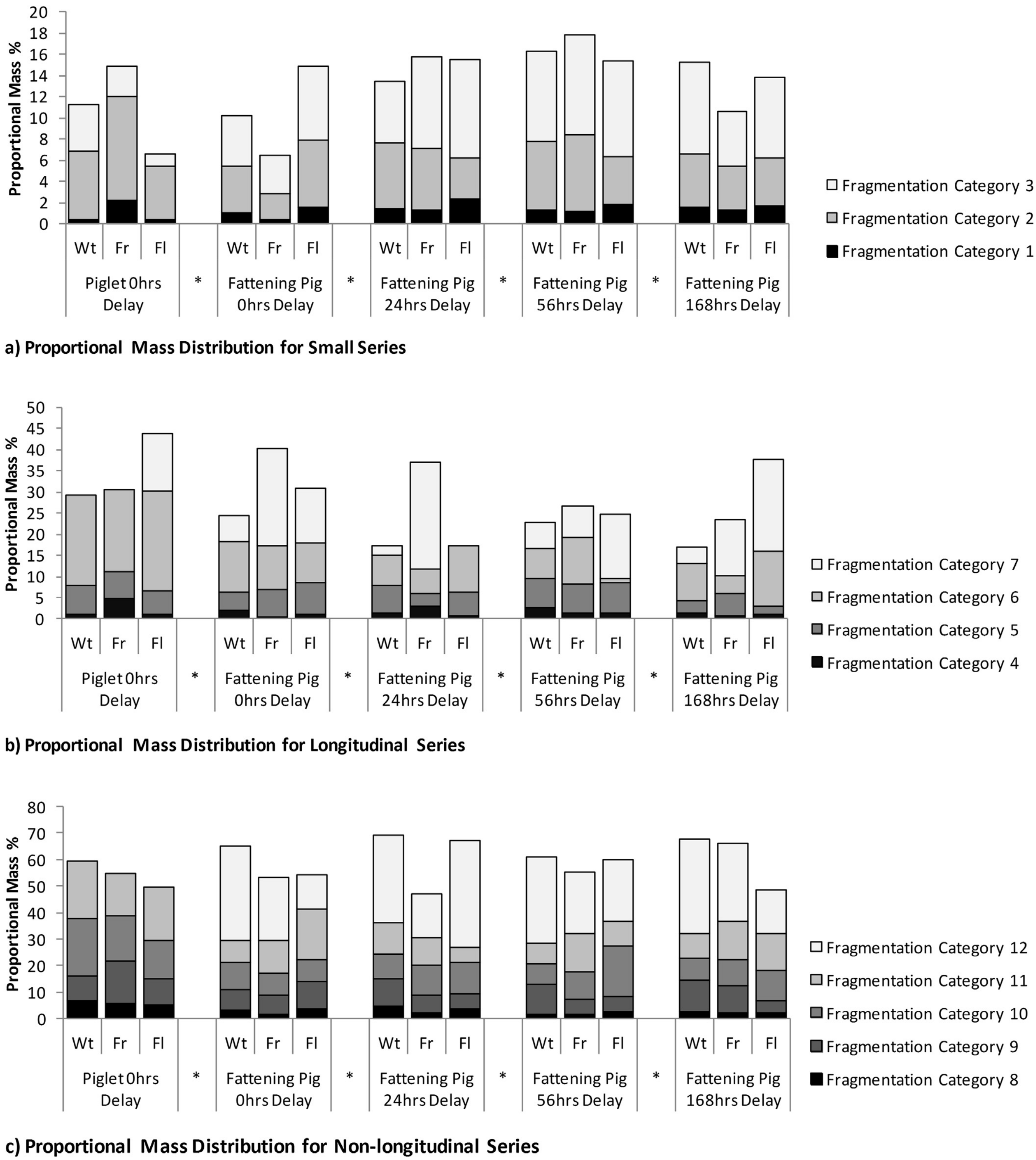

Fig. 2. Proportional mass distributions for piglet and fattening pig remains recovered following different delay periods.

categories. This patterning suggests higher levels of fragmentation in the Freezing burn, intermediate levels in the Wet burn and lower levels in the Fluctuating burn. In contrast to this, proportional masses recorded for the fattening pig remains recovered at 0 h delay indicate the highest levels of fragmentation in the Fluctuating burn, intermediate levels in the Wet burn and lowest levels in the Freezing burn. These differing responses to weather conditions suggest some age or size specificity of fragmentation as both sets of remains were burned in the same fire and recovered at the same time.

When recovery of remains is delayed the effect of weather on fragmentation is altered (Fig. 2a). When recovery is delayed by 24 h proportional masses in the Freezing and Fluctuating burns show minor differences suggesting little difference in fragmentation, although there may be some increased fragmentation of Category 2 material in the Fluctuating burn. The Wet burn proportional masses suggest increased fragmentation of Category 3 material compared to the two cold weather burns. At 56 h delay proportional masses show little difference in Categories 1 and 3 across all three burn events. For Category 2 proportional mass is markedly lower in the Fluctuating burn suggesting increased fragmentation in this burn event. The expected concurrent increase in Category 1 fragments is present but very small; however, increased fragmentation in Category 2 might have produced fragments too small for collection and analysis rather than becoming Category 1 fragments. When remains recovery is further delayed to 168 h the highest levels of fragmentation are observed in the Freezing burn with the lowest levels in the Wet burn.

3.2. Longitudinal series

Proportional mass distributions for Categories 4–7, the Longitudinal series, are shown in Fig. 2b. As was seen in the Small series the piglet remains recovered at 0 h delay recorded the highest fragmentation levels in the Freezing burn and the lowest levels in the Wet burn. No Category 7 material was recovered in either the Freezing burn or the Wet burn suggesting higher fragmentation in these burn events than in the Fluctuating burn where Category 7 material was recovered. The lowest proportional mass for Category 6 material and the highest for Category 4 material was observed in the Freezing burn indicating higher fragmentation than in the Wet burn. For fattening pig remains recovered at 0 h delay the differences in fragmentation again mirror those seen in the Small series with the highest levels of fragmentation in the Fluctuating burn and the lowest levels in the Freezing burn. The Freezing burn shows higher proportional masses for Categories 6 and 7 and lower proportional masses for Categories 4 and 5 when compared to the Fluctuating burn indicating a better survival of larger fragments. Proportional masses in the Wet burn indicate increased fragmentation of Category 5 and 7 material resulting in higher proportional masses in Categories 4 and 6. This alternating pattern suggests an intermediate level of fragmentation as there is better survival of material from Categories 4 and 6 than seen in the Fluctuating burn.

When remains recovery is delayed by 24 h we see the highest levels of fragmentation in the Fluctuating burn, where no Category 7 material was observed. The Freezing burn shows the lowest levels of fragmentation with the highest proportional mass in Category 7 and the lowest in Categories 5 and 6. The Wet burn shows an intermediate level of fragmentation with some survival of Category 7 material but also some fragmentation increasing proportional mass in Categories 5 and 6. When recovery is further delayed to 56 h the Fluctuating burn shows the lowest levels of fragmentation with a high Category 7 and low Category 6 proportional masses suggesting that if Category 7 material survives a delay of 24 h it is relatively stable at 56 h delay. In contrast the Freezing burn shows the highest levels of fragmentation of larger Category 7 material after 56 h delay. Proportional masses in the Wet burn indicate balanced fragmentation across all categories with no single category dominating the proportional mass distribution. As seen at 56 h delay, at 168 h delay the Fluctuating burn shows the lowest levels of fragmentation with high proportional masses in Categories 6 and 7 and low proportional masses in Categories 4 and 5. The Wet burn shows the highest level of fragmentation with increased destruction of material from Categories 5 and 7 compared to the Freezing burn.

3.3. Non-longitudinal series

Proportional mass data from the Non-longitudinal series is presented in Fig. 2c. For the piglet remains, as in the Small and Longitudinal series, highest fragmentation is seen in the Freezing burn. This burn had the lowest proportional masses for Category 11 (no Category 12 material was observed for any burn event) and highest proportional masses for Category 9. There seems to be little difference in fragmentation between the Fluctuating and Wet burns which show similar proportional masses for all categories. The fattening pig remains collected at 0 h delay also show a similar pattern to that previously described with highest fragmentation in the Fluctuating burn and lowest fragmentation in the Freezing burn. The Fluctuating burn shows sequential rises and falls in proportional mass with low values in Categories 10 and 12 and high values in Categories 9 and 11. Proportional masses in the Wet burn also show an undulating pattern, but with peaks in Categories 10 and 12 indicating less fragmentation compared to the Fluctuating burn. Compared to the Freezing burn the Wet burn shows less fragmentation of Category 12, but higher proportional masses in Categories 8, 9, and 10 suggest an overall slight increase in fragmentation in the latter burn event.

When remains recovery is delayed the patterns of fragmentation are altered (Fig. 2c). After a delay of 24 h proportional masses in the cold burns suggests more fragmentation of larger fragments in the Freezing burn compared to the Fluctuating burn which has higher Category 12 proportional masses and lower Category 11 material. Proportional mass distribution in the Wet burn suggests less fragmentation in the larger categories (Categories 11 and 12) compared to the Freezing and Fluctuating burns with apparent slight increases in fragmentation of intermediate Categories, 9 and 10. When recovery is delayed 56 h highest fragmentation is seen in the Freezing burn as was observed in the Longitudinal series. The Wet burn and the Fluctuating burn show rise and fall changes in proportional mass between categories where a higher level in Category 10 corresponds with lower levels in Categories 8 and 9 in the Fluctuating burn, and higher levels in Category 9 correspond with lower levels in Category 8 in the Wet burn. This pattern is not observed in the Freezing burn indicating increased fragmentation in this burn event as fragmentation is more evenly distributed across all categories. With further delays in recovery (168 h) cold conditions again impact fragmentation more than wet conditions. The Wet burn shows high Category 12 material with low proportional masses in Categories 11 and 10. This is opposite to the pattern seen in the Fluctuating burn where low Category 12 proportional masses and high proportional masses in Categories 11 and 10 indicate increased fragmentation. The low proportional masses in Category 9 however suggest less fragmentation of smaller material in this burn event. The Freezing burn shows intermediate levels of fragmentation with breakdown of Category 12 material resulting in increased proportional masses in Categories 9–11.

4. Discussion

Fragmentation patterns differed considerably for piglet and fattening pig bone exposed to different weather conditions. These patterns can be interpreted and provide clues as to how some

weather factors affect the fragmentation of calcined bone. In fattening pig remains recovered the day after burning the fragmentation levels are higher for all series when ambient scene temperatures fluctuate around freezing than when temperatures remain well below 0 °C. This result cannot be attributed solely to the fragment-producing effect of freeze–thaw cycling in the fluctuating conditions as both sets of remains (Freezing burn and Fluctuating burn) experienced a single freeze-thaw cycle with thawing occurring either in the field (fluctuating conditions) or the laboratory (freezing conditions). In-the-field thawing may have resulted in the loss of some bone pieces too small for recovery; however, these fragments would have been excluded from analysis of the remains from the Freezing burn as they would have been below the defined reliable collection threshold. The difference in fragmentation observed between the Fluctuating and Freezing burn must then be attributed to differences in the rate of freezing. In the Fluctuating burn the minimum overnight temperature recorded was −5 °C compared to −19.5 °C in the Freezing burn, indicating a clear difference in the gradient of temperature loss. In the Freezing burn, any moisture in and around the bone surfaces would have frozen sooner than in the Fluctuating burn, reducing the amount of liquid moisture within the bone fragment. How the increased exposure to liquid moisture in the Fluctuating burn results in increased fragmentation is unclear, although anecdotal experience of working with damp calcined remains suggests it may relate to moisture penetrating micro-fissures and cracks weakening the overall bone structure.

The effect of a slower cooling period and in-field thaw increasing fragmentation does not explain fragmentation in piglet remains. In this case the highest levels of fragmentation for all series were observed when temperatures remained well below freezing, with less fragmentation observed in situations with fluctuating temperatures. This age based difference may relate to the fact that although the collected piglet bone showed higher proportional masses in the smaller categories, the bone material was typically less fragmented, with more complete or almost complete bone elements and unfused epiphyses than the fattening pig material. These more complete bone pieces, while still containing no organic material and having no elastic capacity, are better able to withstand the stresses and strains introduced by the penetration of moisture into the bone fragments. As almost complete bone pieces, and not isolated fragments, the piglet material retains more strength and stability, enabling it to survive some structural weakening, and thus fragment less than the fattening pig material under the same conditions. The resistance to fragmentation in piglets may also result from the smaller initial size of the material. Smaller bones may fragment less during the burning process as they experience less difference in micro-environment across a single bone surface ensuring more bones remain complete in the post-burning environment.

When remains recovery is not completed the day after burning, the conditions experienced in the Fluctuating and Freezing burn differ, not only by the rate of cooling, but also by the number of freeze-thaw events. In the Fluctuating burn any moisture within the bone expands and contracts with each freeze-thaw cycle and in the freezing conditions this expansion only occurs on first freezing and contraction on final thawing in the laboratory. Thus the Fluctuating burn remains experience a dynamic changing environment compared to the more static situation in the Freezing burn remains. These Freezing burn remains do experience change as the continued exposure to cold temperatures allows for deeper penetration of freezing over time. How these differences affect bone fragmentation depends on time until recovery and bone fragment size and shape. When recovery is delayed by 24 h freeze-thaw cycling has a greater effect on fragmentation of the Small and Longitudinal fragments, but not the Non-longitudinal fragments, possibly because these fragments are often more structurally complete. As was observed when comparing the piglet and fattening pig material, at 24 h delay the Non-longitudinal series consisted of markedly more nearly-complete fragments than the Small and Non-longitudinal series. This structural integrity would have offered some resistance to the fragmenting effects of the freeze-thaw cycles. At 56 and 168 h delay higher fragmentation is seen at temperatures below freezing in almost all series and time periods, indicating that in the longer time frame the effect of freeze–thaw cycles is less significant than continued exposure to below 0 °C temperatures. This loss of fragmentation effect over time in fluctuating temperatures suggests that after two or three freeze–thaw events, repeated events do not induce further fragmentation.

In addition to the effect of freezing, moisture impacts fragmentation through rainfall. Remains from the Wet burns for piglet and fattening pig material collected the day after the fire typically showed fragmentation levels falling between the two other burns, suggesting that the rainfall experienced during recovery increased fragmentation. Recovery of this material was made in the rain, following periods of overnight rains; thus, remains were damp during recovery and needed to be dried in the laboratory before processing. The dampening process would lead to increased fragmentation as moisture would have gained access to micro-fissures and cracks in the calcined bone, weakening the structure. When the material dried, the loss of water will have again altered the pressures and strains experienced by the bone which may have lead to further fracturing. The traumatic effect of raindrop impact is another factor which may have caused increased fragmentation.

When recovery is delayed the effect of rainfall on fragmentation becomes more complicated. At 24 h delay, fragmentation patterns suggest that larger fragments are able to withstand the effects of rainfall and fragmentation does not increase in these categories, but at 56 and 168 h delay the effect of rainfall is again apparent. This pattern highlights the time specificity of the effect of rainfall with remains able to withstand the effects of moisture for only short periods of time.

5. Conclusion

The fragmentation of calcined bone is very complex and highly nuanced with many factors having a significant impact on how bone responds to the burn environment and how fragmentation occurs. Data presented here show that fragmentation patterns are age and time specific, and are affected by weather conditions such as freeze–thaw cycles and rainfall. Knowledge of how these factors affect fragmentation allows investigators to implement protocols to minimise post-burning fragmentation by limiting remains exposure to moisture and freezing temperatures. Remains recovery can be delayed by factors such as scene safety or difficulties in locating remains and in these circumstances remains should be kept in a stable environment, prevented from freezing and protected from rainfall through the use of protective coverings and heating prior to and during recovery. If these steps are taken, remains recovery can be enhanced by limiting weather induced additional destruction of the remains. If it is not possible to protect the remains in this manner knowledge of the effect of these weather conditions on fragmentation allows investigators to develop scenario-specific recovery timelines and procedures to maximise remains recovery. It should be noted that while these data provide valuable direction for investigators they do not address all potential burn environments or weather conditions that may affect fragmentation. Further research into the effect of fire type and other weather factors such as snowfall, hail, high winds, and extreme high temperatures, will enable further refinements and detail on the effect

of weather conditions on burnt bone fragmentation. As the aim of the research reported here was to initiate work in ways to improve recovery procedures to optimize remains collection, it is premature at this stage to use this data for other purposes such as determining time-since-burning intervals in investigative case work, though it is anticipated that continuing research will open up these possibilities and perspectives.

Conflicts of interest

None.

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None.

Ethical approval

University of Alberta.

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